Protection against ultraviolet and visible radiation used in medical therapy

T. Christensen

Norwegian Radiation Protection Authority (NRPA), P.O. Box 55, NO-1332 ØSTERÅS, Norway
E-mail: terje.christensen@nrpa.no

Abstract. There is an increasing number of applications for UV and visible radiation in medical therapy and diagnosis, and in areas related to cosmetology. All these applications pose risks of unwanted exposure of the staff executing the treatment and the patients.

A new survey in Norwegian hospitals accounting for the status of radiation protection in phototherapy will be presented.

The survey concludes that the occupational dose limits recommended by ICNIRP are not exceeded under normal use of UV therapy in departments of dermatology. The selection of spectra and patient doses are mostly based on experience as well as on information from the suppliers of equipment, who also normally deliver the radiometers used for dose control.

The quality of the equipment used for blue-light phototherapy of newborns has improved since 1992. Compared to the previous survey, more suitable light sources are used, and the irradiance of the equipment is higher today than 12 years ago. A standard for phototherapy of newborns (IEC 60601-2-50, Medical electrical equipment-Part 2-50) is poorly known among the hospital departments. Particularly is the required dosimetry seldom performed and the permitted UV content of the therapy lamps is not routinely assayed (an effective UV irradiance of 10^{-5} mW/cm^2 is the limit). Blue light may cause photochemical damage to various organs. The eyes of the patients are routinely protected in order to avoid blue light-induced photochemical damage to the retina.

Photodynamic treatment (PDT) of cancer and other diseases is performed by combining a photosensitizer and intense red or infrared radiation. Little is known about the potential side effects of the various sensitizers, but eyes and skin have been identified as critical organs. Standardized light regimens do not exist at the moment except for recommendations from the manufacturers of photosensitizers and light sources.

1. Introduction

Non-ionizing optical radiation has been used for therapeutic purposes for centuries, but artificial radiation sources have only been available for about one hundred years. Modern sources can be constructed to give almost any irradiance and spectrum. Several applications of UV and visible radiation have been developed and the volume of phototherapy seems to increase [1,2]. A number of new methods have been introduced recently, e.g. treatment of skin conditions such as actinic keratosis and basal cell carcinoma as well as treatment of cosmetic conditions with optical radiation.

Radiation protection of patients and staff and optimization of the therapeutic methods need to be addressed since many of the applications use radiation that can cause harmful health effects if out of proper control.

NRPA performed a survey of the use of optical radiation in Norwegian hospitals in the early 1990’s [3,4]. A new survey was conducted in the period 2002 – 2004. This paper presents the summarized results from the newest survey. Comparisons are made with the data from the first reports.
2. Methods

2.1. Radiometry

The irradiances and weighted irradiances were measured with the following radiometers: 1) United Detector Technology radiometer 271 with probes 268 Blue or 247 Visible and 2) Solar Light PMA 2100 radiometer with UVB-probe 005827 or a CIE weighted probe ("safety probe").

For the estimation of occupational exposure the methods described in the standard CEN prEN 14255-2 [5] were used.

2.2. Survey of hospitals

The previous survey of nine hospitals was reported in [4]. In the new survey, 21 hospitals and clinics were included (two of them were private dermatology clinics). Five of the hospitals had a department of dermatology.

A standard interview guide was prepared and used in all hospitals. It contained the following main items:
1. Routines for quality control and radiation protection
2. Indications and patient categories
3. Instructions for staff
4. Treatment modalities
5. Observed effects and side-effects
6. Control of equipment
7. Observation of treatment and measurements

Included in the latter item was a visit to the departments, observation of the treatment, measurement of the UV/light and interviews with the staff performing the therapy.

3. Results and discussion

3.1. General

All hospitals had routines for quality control of medical technical equipment. Only two of the hospitals had routines for control of the doses of optical radiation implemented in the institution, although all dermatological units performed dosimetry of their units locally. The systems for radiation protection were of uneven quality. A general impression was that the awareness of the need for radiation protection was more pronounced for ionizing radiation than for non-ionizing radiation. Radiation protection of the staff was usually the responsibility of the HSE, Health, Security and Environment officer, while the more specific questions of protection of the patients were the responsibility of the physician in charge of the treatment.

In most hospitals teaching programs of various academic levels were used in order to gain knowledge of medical procedures and instruments. About half of the hospitals used forms where a signature of the supervisor and the employee had to be obtained at the completion of an instruction program. Some departments had a low staff turn-over. The staffs in these departments were typically very experienced and had no need for written routines. However, a need for documentation of the procedures for their successors was identified.
3.2. **UV therapy**

Few changes in the application of UV-therapy had been made during the study period. The main difference was the increased use of narrow-band UVB tubes since the last survey. The previous report [3] concluded that there were differences between instruments used for measuring patient doses. However, the dosimetry was satisfactory as long as the relative changes in the irradiance values were followed and used for planning of the patient doses. This observation is still valid, but there is a need for standardization of patient doses and dosimetry. A standard like the IEC-standard for phototherapy of newborns [6] has been suggested [7].

A test of the working environment was performed with respect to the limit values of ICNIRP [8]. The general conclusion was that no member of the staff was exposed to doses over the limit value during a regular work shift. The measurements were performed as a survey measurement [5], and an example of the results is given in Table I.

<table>
<thead>
<tr>
<th>Position</th>
<th>E (µW/cm²)</th>
<th>Time before the dose limit is exceeded</th>
</tr>
</thead>
<tbody>
<tr>
<td>UVB hand and foot treatment unit. Distance 3 m</td>
<td>0.6</td>
<td>110 min</td>
</tr>
<tr>
<td>Distance 2 m</td>
<td>1.5</td>
<td>45 min</td>
</tr>
<tr>
<td>Distance 1 m</td>
<td>3.5</td>
<td>20 min</td>
</tr>
<tr>
<td>Distance 0 m</td>
<td>15</td>
<td>4 min</td>
</tr>
<tr>
<td>Waldmann. 8006K, in front of door</td>
<td>0</td>
<td>Indefinite</td>
</tr>
<tr>
<td>- , upper edge of door</td>
<td>0.11</td>
<td>Ca. 8 t</td>
</tr>
</tbody>
</table>

In analyzing the staff work tasks, the conclusion was that the time spent at positions where the irradiance values were higher than 0.1 µW/cm² was considerably shorter than the maximal times mentioned in Table I. On the other hand, the hand and foot treatment unit was placed in an open area, and in order to limit the potential exposure further, a shield was placed around the unit [9].

3.3 **Phototherapy of newborns**

The quality of the equipment used for blue-light phototherapy of newborns has improved since 1992 [4]. Compared to the previous survey, more suitable light sources are used, and the irradiance of the equipment is higher today than 12 years ago (Fig. 1).
FIG. 1. Values of irradiance measured at the position of the patient in the previous and new survey. Each bar is an individual phototherapy unit, and the irradiance has been measured with a probe sensitive only to blue light (United Detector Technology radiometer 271 with probes 268 Blue).

Part of the increase in mean irradiance from 0.9 to 1.7 mW/cm² is due to the more frequent use of reflecting cloths around the phototherapy units.

An international standard for phototherapy of newborns [6] is poorly known to the staff in the hospitals participating in this study. Particularly is the required dosimetry seldom performed and the permitted UV contents of the therapy lamps is not routinely assayed (an effective UV irradiance of $10^{-5}$ mW/cm² is the limit [6]).
The blue light sources with emission peak at approx. 450 nm may vary in size and the distance to the patient is also variable. A worst case is estimated to give an angular subtence of $\alpha = 0.1$ rad. Since the irradiance may vary between 0.4 and 4 mW/cm$^2$, the estimated maximal blue light radiances, $L_b$, in the phototherapy units may vary between 4 and 40 mW/cm$^2$ sr. Some phototherapy units may exceed the limit values [8]. The newborn patients should wear eye protection, and great care must be taken that the protection is on at all times. Particular consideration should be paid to the possibility that the newborn eye may be especially vulnerable to blue-light damage due to both higher transmission (significant for $\lambda < 440$ nm) and less avoidance. It was found that all the hospitals had routines for the use and control of eye protection.

The duration of the treatment is one to several days, normally only interrupted by care and feeding of the infant. Compared to any other form of phototherapy, the radiant exposure of the infant is high; typically in the order of 200 J/cm$^2$ (PDT, typically 50 J/cm$^2$). Therefore the presence of natural or other photosensitizers may be a potential risk for the infant. [10,11]

The exposure of staff was judged as minimal.

### 3.4. Photodynamic therapy

Photodynamic treatment of cancer and other diseases is performed by combining a photosensitizer and intense red or infrared radiation. Little is known about the potential side effects of the various sensitizers, but the eyes and the skin have been identified as critical organs. Standardized light regimens do not exist at the moment except for recommendations from the manufacturers of photosensitizers and light sources.

Two types of equipment were found in the survey: Broad spectrum lamps with emission peak in the red and narrow band lamp based on LEDs with emission at 630-640 nm. No emission in the UV could be measured. The risks of ocular damage by LEDs have been judged as minimal [12], and possible thermal hazards to the skin of the patients may be evaluated. The irradiance at the skin surface can be estimated to a maximum of 200 mW/cm$^2$, and the duration of a typical treatment session is 10 – 15 min. Exposure to patient skin can be evaluated according to the ICNIRP guidelines [8] ($H = 3.6$ J/cm$^2$ for 10 s exposure However, the limit value is defined only up to a maximal exposure time of 10 s) and ACGIH TLV for laser irradiation in the red ($E = 200$ mW/cm$^2$). The conclusion is that the exposures used are between 50 and 100 % of the respective limit value. It should be noted that the normal avoidance behavior is not functional in patients undergoing PDT. On the other hand, cooling devices are often available. It is important to stress that the limit values are given for persons who are not photosensitized. A patient undergoing PDT receives a photosensitizer, either locally or systemically. Therefore, possible photodynamic hazards should be determined in order to protect the patient properly.

It was found that patients and staff used suitable protective goggles during the light exposure.

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References